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71 Applicant: **Davies, David Wyn, Department of Cardiology
St.Bartholomews Hospital, London E.C.1 (GB)**

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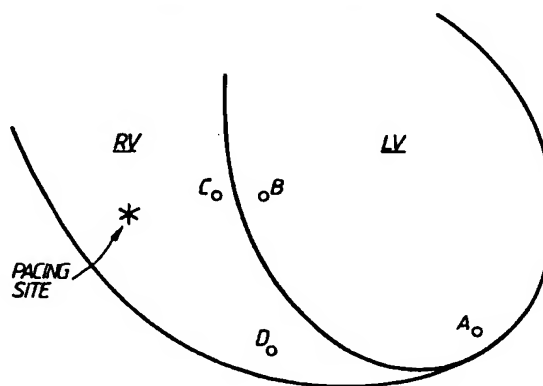
72 Inventor: **Davies, David Wyn, Department of Cardiology
St.Bartholomews Hospital, London E.C.1 (GB)**

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74 Representative: **Silverman, Warren et al, HASELTINE
LAKE & CO. Hazlitt House 28 Southampton Buildings
Chancery Lane, London WC2A 1AT (GB)**

54 **Apparatus for recognition of ventricular tachycardia and ventricular fibrillation and for termination thereof.**

57 Apparatus for the automatic recognition of ventricular tachycardia and ventricular fibrillation compares pulse sequences which are obtained when sensing at at least one position on each ventricular epicardial surface of a heart. Changes in the sequence of activations and in the timing from pulsing at one sensor position to next pulsing at that position will indicate both ventricular tachycardia and ventricular fibrillation to enable a response to be made to restore to a pulse sequence representing the normal ventricular activity of the heart.



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1 APPARATUS FOR RECOGNITION OF VENTRICULAR TACHYCARDIA AND
2 VENTRICULAR FIBRILLATION AND FOR TERMINATION THEREOF

3 This invention relates to apparatus for
4 recognition of ventricular tachycardia and ventricular
5 fibrillation from epicardial electrogram timings and for
6 termination thereof.

7 Ventricular fibrillation is defined as a condition
8 characterised by fibrillary electrical activity of the
9 ventricular muscle, the electrical impulses traversing
10 the ventricles so rapidly that coordinated contractions
11 cannot occur. This must be distinguished from
12 ventricular tachycardia which may be defined as a rapid
13 (greater than 110 beats per min) cardiac rhythm
14 originating in the ventricles. If sustained, it is
15 usually synchronised in terms of overall ventricular
16 contraction. Both should be differentiated from the
17 normal situation of sinus rhythm where the heart's rhythm
18 is controlled by depolarisation originating from the
19 sinus node and which spread sequentially through the
20 atria, the AV node, the His-Purkinje system and
21 ventricular myocardium.

22 It is an object of the invention to provide
23 apparatus for recognizing both ventricular tachycardia
24 and ventricular fibrillation to be used with means for
25 responding to both these conditions to restore normal
26 heart rhythm.

27 According to the present invention, there is
28 provided apparatus for the automatic recognition of
29 ventricular tachycardia and ventricular fibrillation
30 comprising:

31 at least two sensors for attachment of at least
32 one sensor to each ventricular epicardial surface of a
33 heart;

34 signal paths connecting the sensors to programmed
35 means for detecting a pulse sequence representing the
36 ventricular electrical activity of the heart and for
37 comparing the pulse sequence detected with that

1 representing the electrical activity of the heart during
normal ventricular rhythm of the heart; and

means for converting the detected pulse sequence
into a form which will be useful for providing a
5 corrective response to a pulse sequence representing the
electrical activity of the heart during abnormal
ventricular rhythm of the heart. The apparatus will
generally be used in association with means for supplying
to the heart stimuli to restore normal rhythm to the
10 heart following detection of abnormal ventricular rhythm,
in which case there may be no need for converting the
detected pulse sequence into a readable form or other
form, such as audible form, which makes a pulse sequence
representing electrical activity of the heart during
15 abnormal ventricular rhythm of the heart to be
identified.

For a better understanding of the invention and to
show how the same can be carried into effect, reference
will now be made, by way of example only, to the
20 accompanying drawings wherein:-

FIGURE 1 shows schematically an arrangement of
four ventricular activation sites;

FIGURE 2 shows the electrograms obtained from the
four sites during normal sinus rhythm;

25 FIGURES 3A, B and C show electrograms obtained
under simulated ventricular tachycardia conditions;

FIGURE 4 shows the electrograms obtained at the
four sites under conditions of ventricular fibrillation;

FIGURE 5 is a block diagram of a cardiac implant
30 embodying this invention; and

FIGURE 6 is a flow diagram indicating the
characteristic operation of the present invention.

The feasibility of automatic recognition of
ventricular tachycardia and ventricular fibrillation has
35 been examined in a number of patients undergoing coronary
artery surgery. Bipolar epicardial electrograms from
four discrete points on the surface of the heart have

1 been recorded during operation. The points are
indicated on the ventricles of the heart. It has been
observed that during normal rhythm, the points which are
recorded are activated in a certain sequence which is at
5 least consistent, although not always specific to that
rhythm. Thus, referring to Figure 1 of the accompanying
drawings, the locations of four discrete points numbered
A, B, C and D on the left ventricle (LV) and right
ventricle (RV) are shown, two of the points (A and D)
10 being on the left ventricular and right ventricular
apices and points B and C being at left ventricular and
right ventricular paraseptal positions. A pacing site is
located on the right ventricle adjacent the third point.
During normal rhythm, activation took place in the
15 sequence C, D, B, A in this particular case (see Figure
2). Furthermore, the timing from the first detected
deflection to the last of the four was always the same
during normal rhythm and in this example, because of
normal rhythm, the timing is short, being of the order of
20 25 msec.

With abnormal rhythm, this timing will generally
be increased and the sequence of activations changed.

This latter observation was established by
simulation of an abnormal rhythm by pacing from the site
25 on the right ventricle. It was observed that 8 out of a
group of 10 patients paced at this particular site showed
a change of sequence of activation compared with that
seen during normal sinus rhythm. Recording of the
sequences obtained showed that activations change from C,
30 D, B, A to C, B, D, A. Another abnormality which was
induced was that because a normal conducting system was
not utilised, the spread of activity took longer across
the heart so that the timing from the onset of
depolarisation detected first at site C and finally at
35 site 1 took 85 msec as opposed to 25 msec. Figures 3A,
3B and 3C indicate that this duration and sequence of
activation is not affected by the rate of the abnormal

- 1 rhythm provided that its site of origin remains constant.
Maintaining the same set of sites, further
experimentation to induce ventricular fibrillation
yielded further results of interest. Ventricular
5 fibrillation was induced by putting AC current onto a
heart under cardiopulmonary by-pass (this is a means of
obtaining cardiac arrest and often used during surgery).
It was observed that during ventricular fibrillation, the
electrical activity at all four sites was extremely
10 rapid, and certainly more rapid than normally seen.
However, there was no apparent fixed sequence of
activation. The activity can therefore be described as
asynchronous. Because of the asynchronous nature of
activity, there can be no fixed duration of activity.
15 This thus provides a means of using multi site testing to
distinguish between ventricular tachycardia where there
is likely to be an altered sequence of depolarisation
compared with normal rhythm and an increased duration of
activation over that occurring during normal sinus
20 rhythm, and ventricular fibrillation when all this
synchrony is lost and the electrical activity from
different points in the heart becomes asynchronous.
- Thus apparatus embodying this invention is
programmed to respond to ventricular tachycardia or
25 ventricular fibrillation when they are detected from an
altered sequence and duration of ventricular activation
as detected by impulses sensed from the epicardial
sensing sites.
- The present invention is of particular value in
30 that ventricular fibrillation has so far been a very
difficult rhythm to detect reliably automatically.
Moreover, the energy required by an implantable device to
treat ventricular fibrillation is likely to be higher
than that required to treat ventricular tachycardia.
35 Therefore by the use of this technique, lower energies
can be selected for termination of ventricular
tachycardia thereby prolonging battery life. There is

1 thus provided a reliable method for the first time of
detecting ventricular fibrillation. The micro-computer
utilised in the circuit for comparing activation sequence
with that during sinus rhythm can then control a
5 defibrillator which can be discharged when rhythm
characteristic of ventricular fibrillation or ventricular
tachycardia is detected. Appropriate software is
provided for controlling the micro-computer.

Finally Figures 5 and 6 show practical embodiments
10 of the invention and should be viewed in conjunction with
each other. Thus an implant 1 which has sensors (not
shown) at positions such as shown in Figure 1) will
monitor heart rate beat at all times using a normal heart
beat detector 2 having time base and backup pacing
15 control 4 whose operation is directed by a microprocessor
5 having a memory 6. Should a high heart rate be
detected, then a detector 3 which is normally operating
in backup mode is switched on and simultaneous
multi-channel sensing is carried out although Figure 1
20 shows that sensing at four sites is carried out, and this
number is adequate in general, there is no reason why
more or less than four sites may be used for testing,
although the use of four sites has been found to be an
optimum compromise between cost and sensitivity. The
25 microcomputer 5 which is utilised with the detector and
receives signals therefrom will check by means of memory
6 whether activation sequence and duration are compatible
with sinus rhythm. If this is the case, then no action
will be required. However, if the activation sequence
30 and duration are not compatible with sinus rhythm, then
provided that an activation sequence is synchronised
indicating ventricular tachycardia, a response
appropriate to treatment of ventricular tachycardia will
be initiated, i.e. stimuli will be delivered by pulse
35 generator 7. In certain cases, which depend on the type
of tachycardia, however, ventricular tachycardia may be
located by a relatively low energy shock for an

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1 associated defibrillator 8. If the activation sequence
is not synchronised, indicating that ventricular
fibrillation is taking place then operation of the
defibrillator 8 will take place.

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1 Claims:

1. Apparatus for the automatic recognition of ventricular tachycardia and ventricular fibrillation characterized by:

5 at least two sensors (A,B,C,D) for attachment of at least one sensor to each ventricular epicardial surface of a heart;

signal paths connecting the sensors to programmed means (2,5,6) for detecting a pulse sequence representing the ventricular electrical activity of the heart and for
10 comparing the pulse sequence detected with that representing the electrical activity of the heart during normal ventricular rhythm of the heart; and

means for converting the detected pulse sequence
15 into a form which will be useful for providing a corrective response to a pulse sequence representing the electrical activity of the heart during abnormal ventricular rhythm of the heart.

2. Apparatus as claimed in Claim 1, which
20 additionally comprises means (7,8) for supplying to the heart stimuli to restore normal rhythm thereto following identification of abnormal ventricular rhythm.

3. Apparatus as claimed in claim 2, wherein said heart stimuli supplying means (7,8) is adapted to supply
25 less energetic heart stimuli in the event of ventricular tachycardia identification than in the event of ventricular fibrillation identification.

4. Apparatus as claimed in Claim 1, additionally comprising means for converting the detected pulse
30 sequence into a readable form.

5. Apparatus as claimed in Claim 1, wherein for any predetermined arrangement of the sensors on the ventricular epicardial surfaces, the programmed means (5,6) is programmed to detect the time interval occupied
35 by a predetermined number of pulses and the sequence of activations, both of which detected parameters are compared by the programmed means with the

1 same parameters when determined during normal rhythm of
the heart.

6. Apparatus as claimed in Claim 5, wherein the
programmed means (5,6) is programmed to detect
5 asynchronous electrical activity at said heart surfaces.

7. Apparatus as claimed in Claim 1, which
comprises four sensors (A,B,C,D) for application two to
each of the two ventricles of the heart.

8. Apparatus as claimed in claim 7, wherein two
10 of the sensors (A,D) are for application to the left
ventricular and right ventricular apices and the other
two sensors (B,C) are for application to the left
ventricular and right ventricular paraseptal positions.

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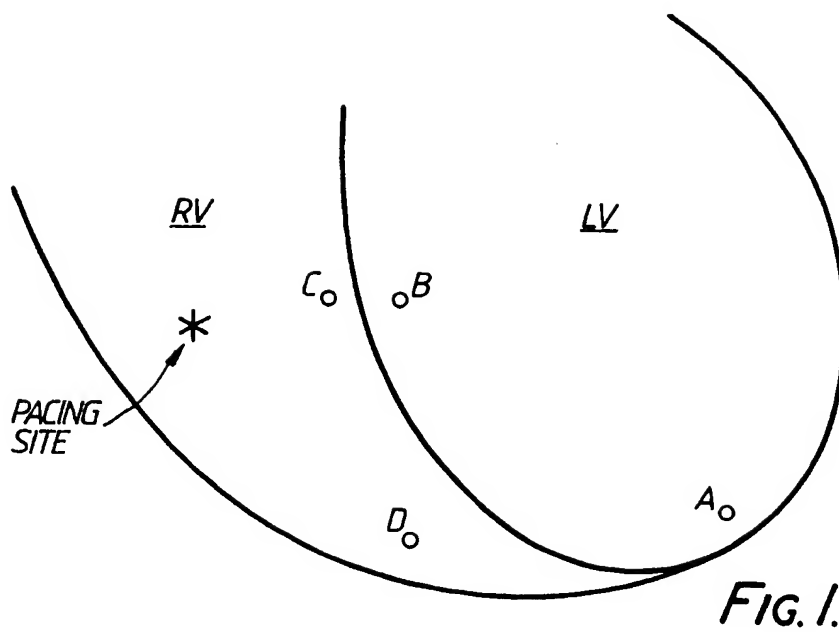


FIG. 1.

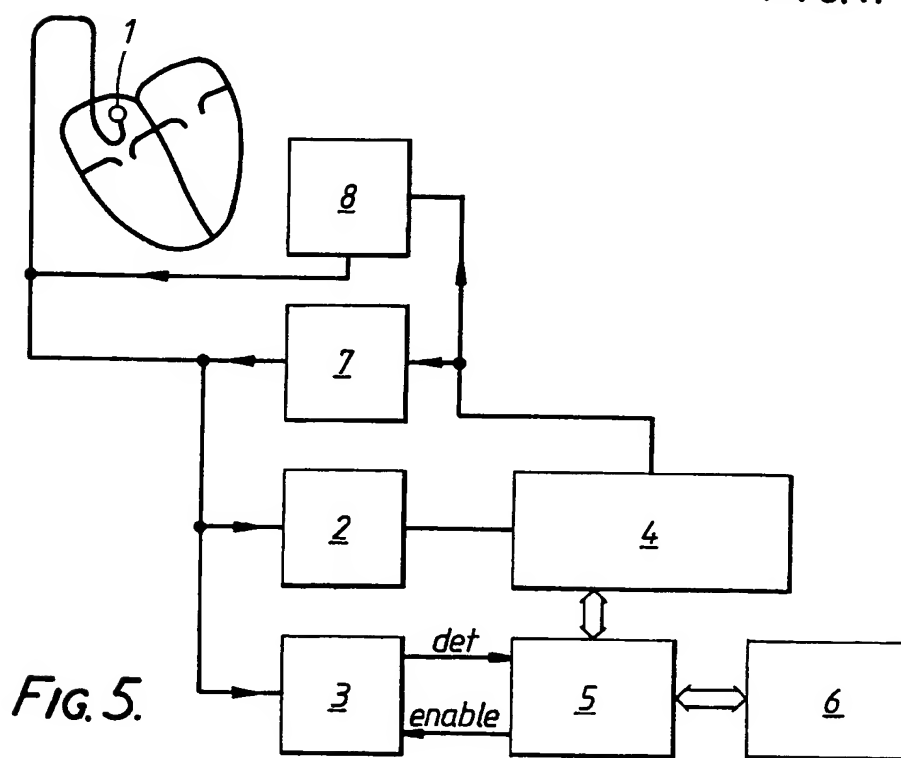


FIG. 5.

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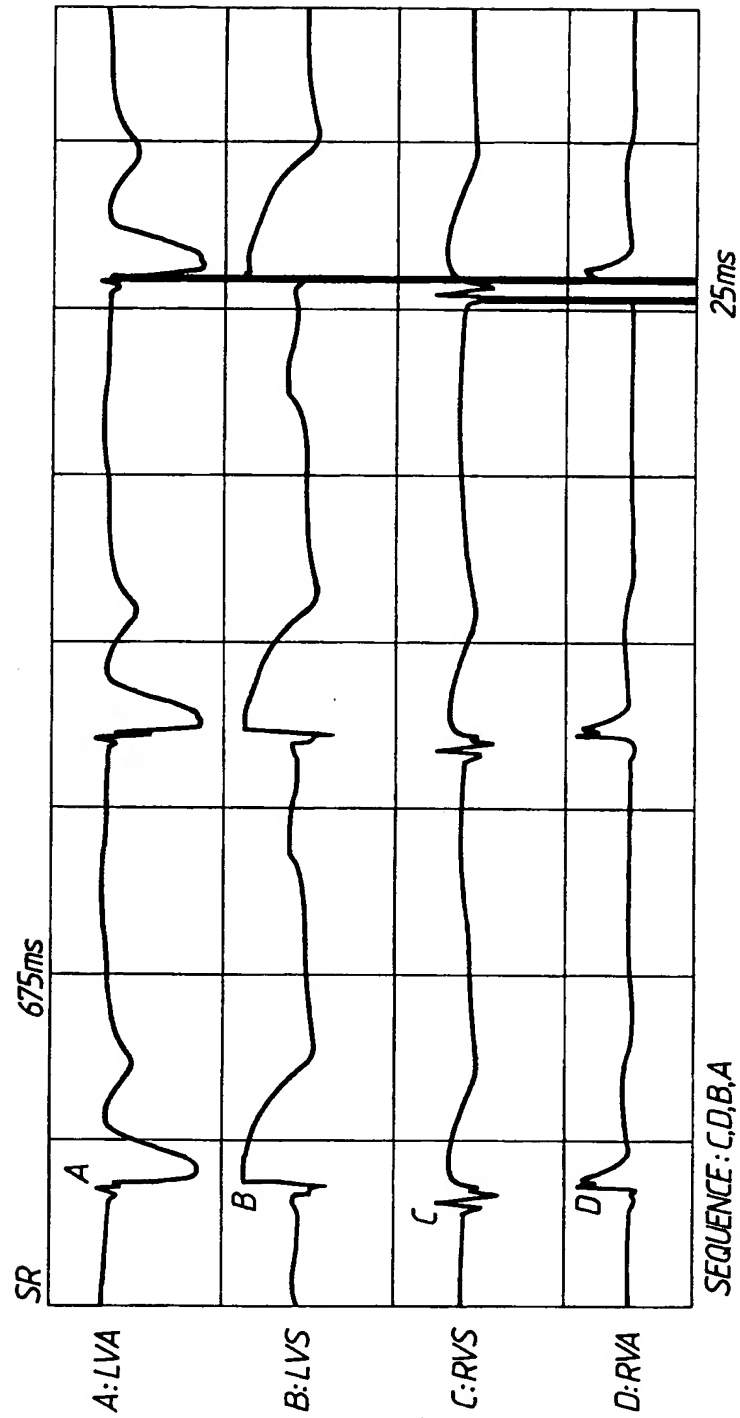


FIG. 2.

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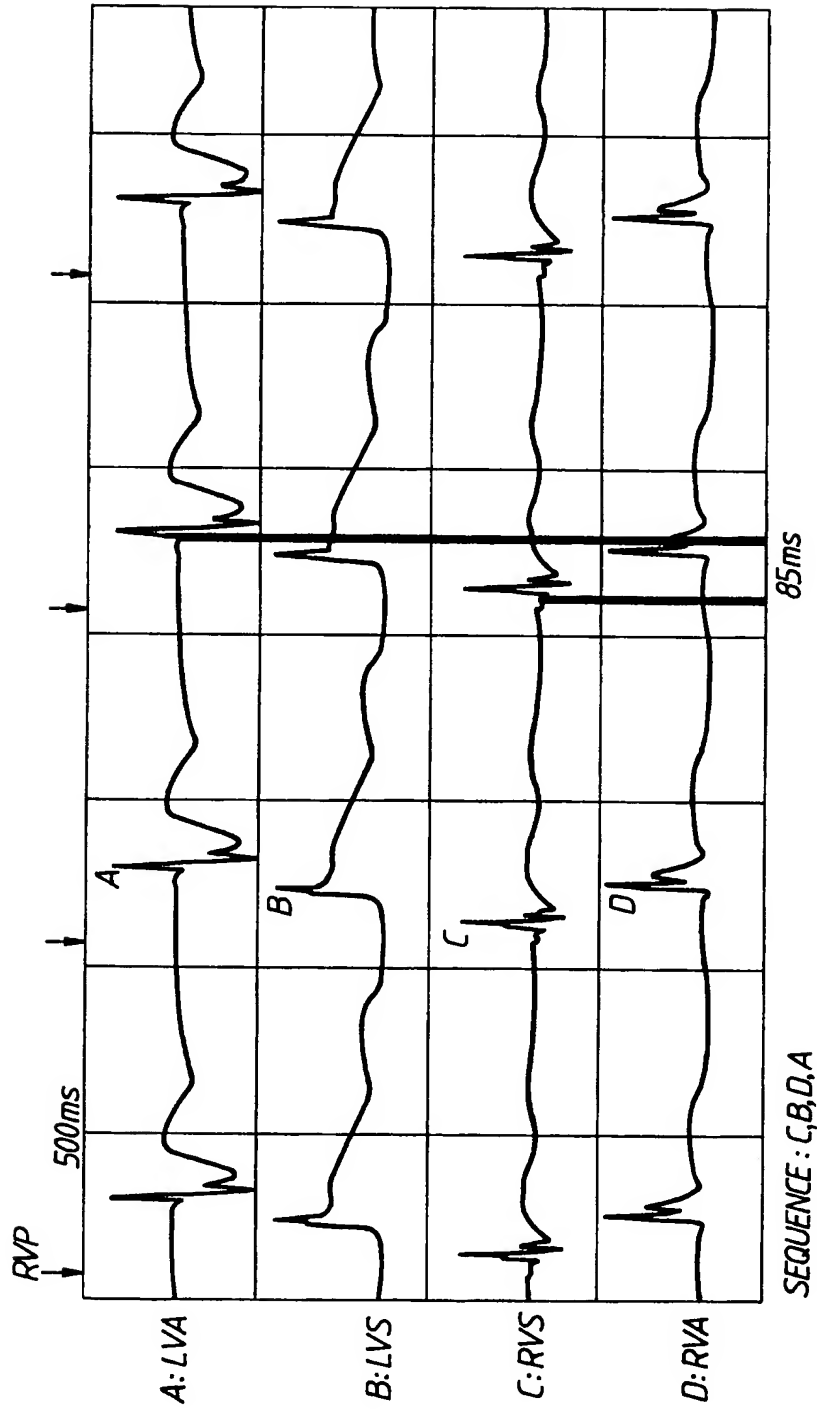


FIG. 3A

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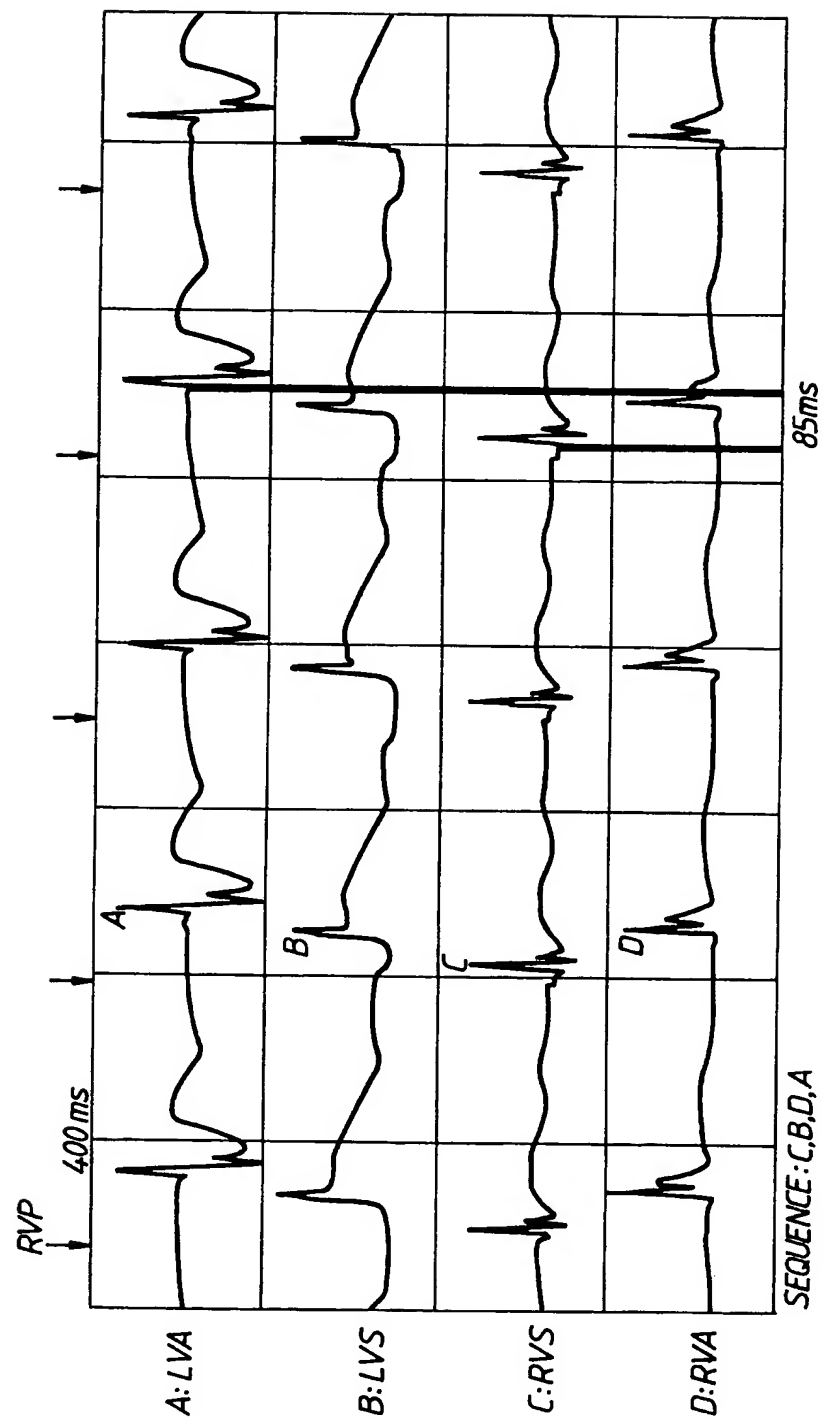


FIG. 3B.

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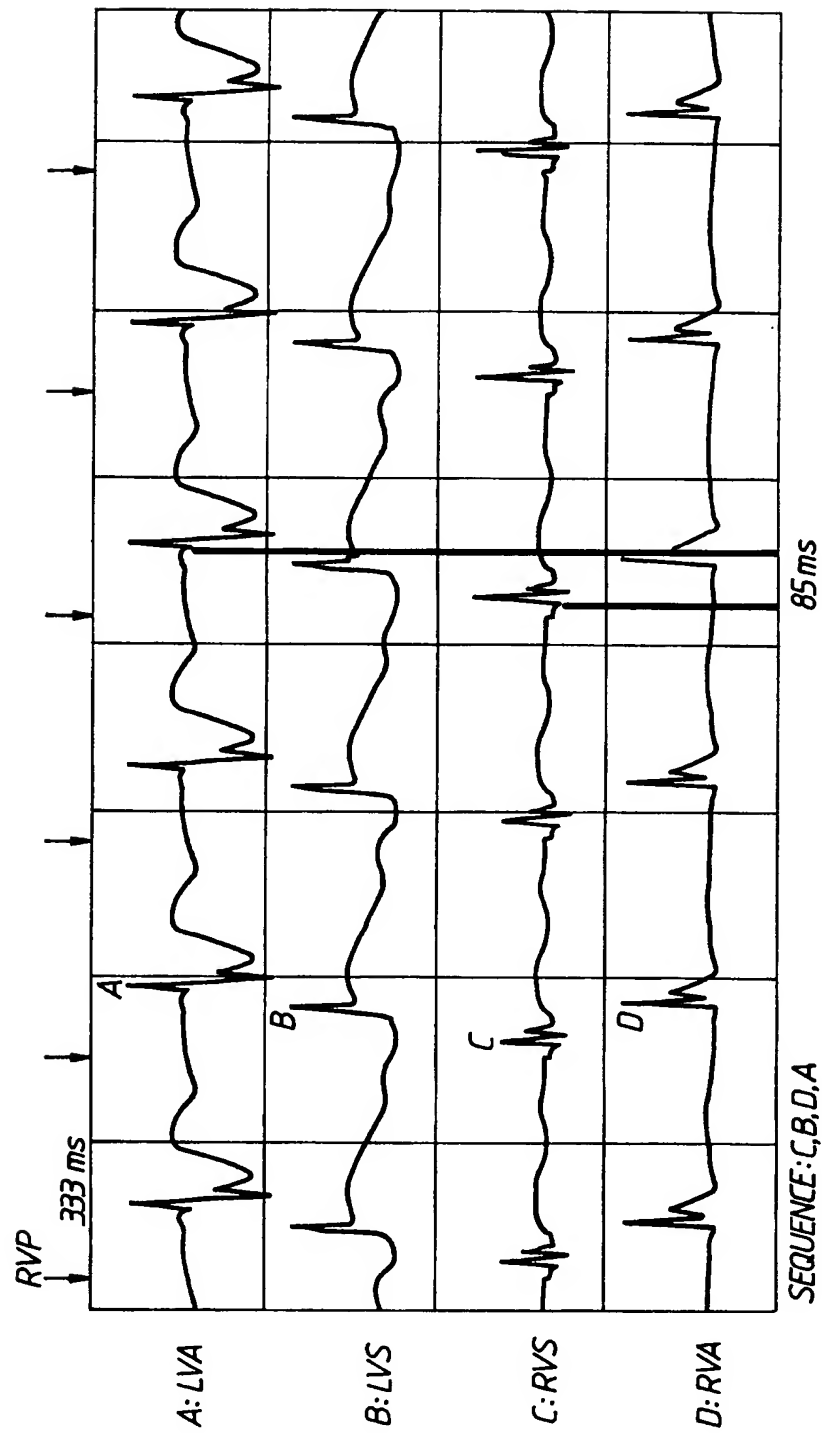


FIG. 3C.

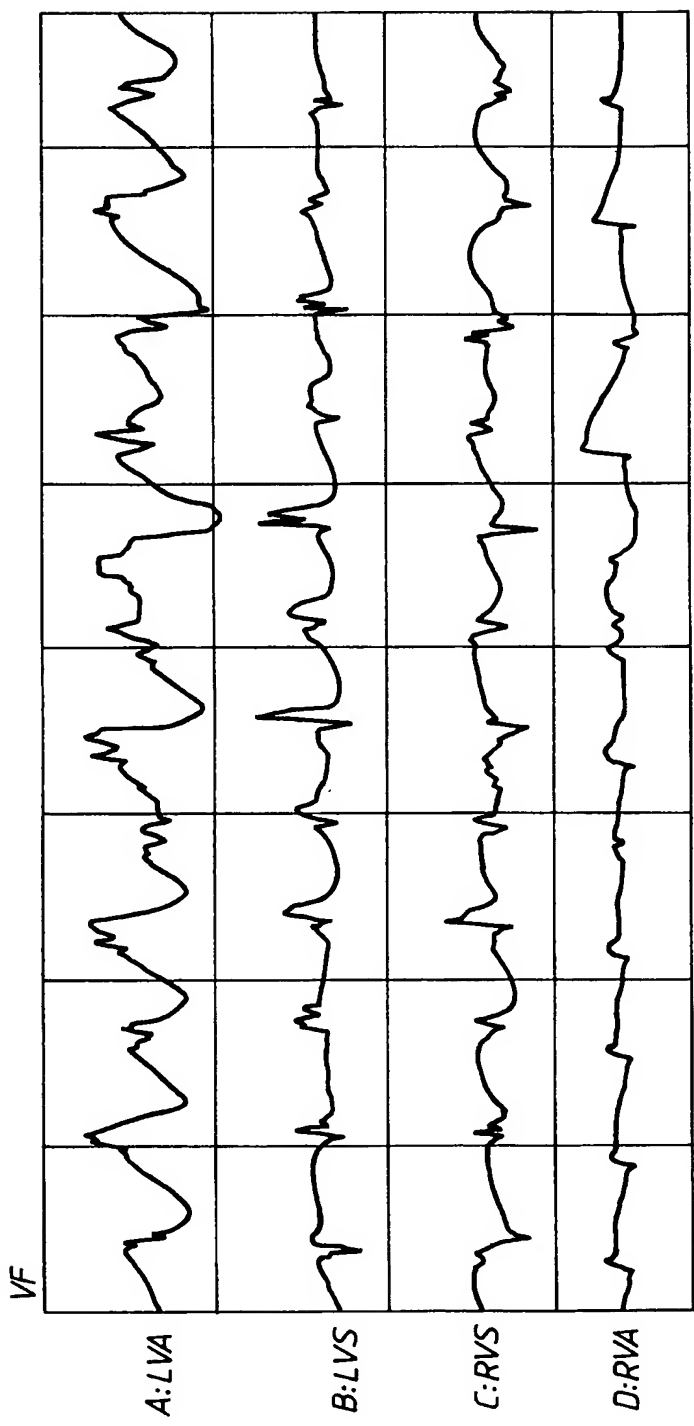


FIG.4.

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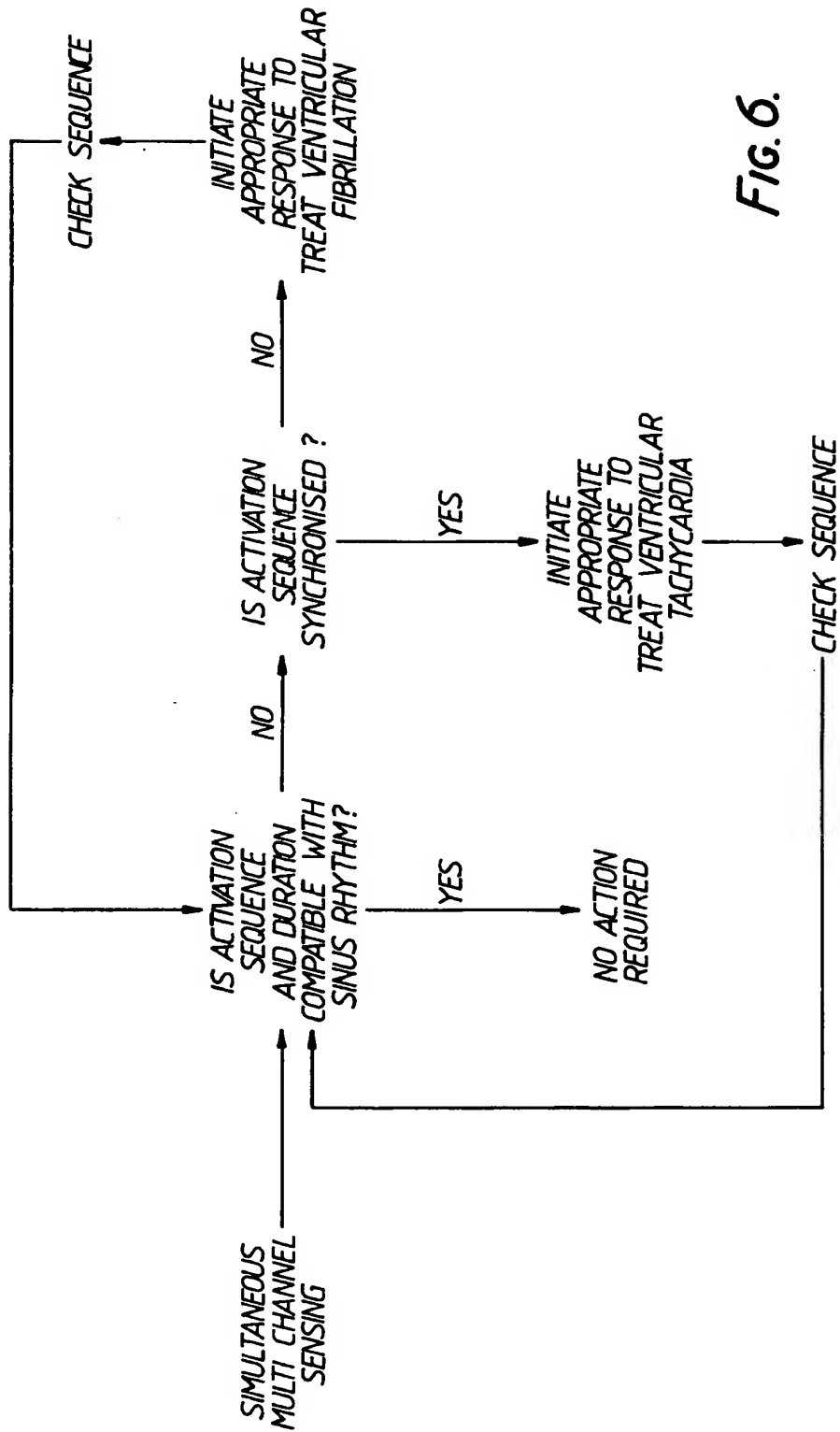


FIG. 6.